

WATER SUPPLY MANAGEMENT -- TRENDS IN CALIFORNIA WATER METERING: A PRELIMINARY ANALYSIS

L.L. Dale

Lawrence Berkeley National Laboratory

N.A. Williams

Loyola College in Maryland, USA

C.D. Whitehead

Lawrence Berkeley National Laboratory

Despite growing water scarcity, many water districts in California sell water to customers on a flat rate basis at a time when many policy makers advise sales on a volumetric basis to conserve water. A transactions cost model clarifies the district choice of water sales practice. The model assumes that districts maximize net consumer benefits when choosing between a flat rate and a volumetric sales option.

The model is used to explain the observed pattern of flat rate and volumetric sale practices in the Central Valley of California and to predict the increase in volumetric sales resulting from an increase in the average cost of water. A logistic regression analysis of this data indicates that local water cost explains much of the variation in water sale practices in the Central Valley, as predicted by the model.

1 INTRODUCTION

In California and other western states, increasing pressures are being placed on scarce water resources. Much of the impetus comes from growth in the urban demand for water – between 1990 and 2000, California's population grew 13.6% to 33.87 million (U.S. Bureau of the Census). While agriculture accounts for over 80% of water use in California, this component of demand has been very static over the past decade, and it is expected to continue that way for the foreseeable future. Thus, although urban demand still is only a small part of total water use, it accounts for almost all of the current growth in total water use. In this context securing an efficient and equitable allocation of water has become an issue of great concern to the State's resource managers.

Although the majority of California's population lives in the coastal areas of Southern California and San Francisco Bay, there are significant urban centers in the Central Valley, including Fresno, Bakersfield and Stockton in the southern portion of the Valley and Sacramento in the northern portion. The urban population in the Central Valley is growing at twice the rate of other urban areas in the State, and there is strong interest to insure efficient urban water use in that region.

A peculiarity of the cities of the Central Valley is that most water services are not metered; that is, most urban water users pay a flat monthly fee for an unlimited supply of water. These residents share the city water supply much like Swiss cantons share grazing areas and their water system is essentially communal.

Communal and incompletely metered water systems in the Central Valley have become the focus of increasing State controversy in recent years as pressures upon limited State water supplies have grown. Those interested in water conservation, the communal water system is attacked as inherently inefficient because it provides users little incentive to conserve water. Indeed, several studies have indicated that per-capita water use in cities with communal water

systems is much higher than water use in cities with metered systems. In response to these pressures, the California State legislature has proposed bills to force State municipalities to meter individual service connections. Many cities have lobbied strongly against such legislation. Sacramento, the state's capital and a prime example, has the largest communal water system in the State. Sacramento's preference for the communal water system is enshrined in its city charter, which forbids residential water service meters. Representatives of Sacramento regularly attend hearings of the State Water Resources Control Board, a state agency responsible for regulating such matters, and lobby against mandated water meters.

The continuation of communal water systems in Central Valley cities, at a time when water is becoming increasingly scarce in many other areas, is therefore the focus of much policy interest. However, of perhaps equal interest are the many cities in the Central Valley, which meter some or all service connections. For example, both Bakersfield and Fresno, the second and third largest cities in the Valley, meter a small percentage of their service connections and many, perhaps most, smaller cities meter all service connections.

The adoption of water service meters, by some cities, and the communal water systems, by other cities, provides a unique opportunity to observe and measure the determinants of this type of institutional choice. This paper proposes a model of urban water district behavior, which explains the pattern and extent of incomplete water metering in Central Valley cities. The paper is divided into five sections. Following this introduction, section two briefly summarizes the relevant transactions cost and institutional choice literature. Section three presents a model, which predicts the extent of water metering in a water district and suggests a testable hypothesis of this model. An econometric analysis of data from urban Central Valley water districts is used to illustrate the model in section four. The concluding section five contains a discussion of the policy implications of the analysis.

The model presented in this paper assumes that the district choice for incomplete water metering is an efficient response to water metering transactions costs. To the degree this model is supported by the data on water metering in the Central Valley, caution is advised against regulations that impose water meters to improve water use efficiency.

LITERATURE REVIEW

Incomplete water metering may be characterized as non-standard market practice (most goods are sold on a volumetric rather than communal basis). Transactions cost economics has provided a useful perspective for explaining non-standard practices as means to economize on the transactions costs of the market (Coase 1937; Demsetz 1967; Williamson 1985). The existence of the firm, non-standard modes of organization, such as vertical integration, and non-standard sales methods, such as block booking and tie-in sales, have all been explained as measures to economize on transactions costs (Coase 1937; Williamson 1985; Kenny and Klein 1983).

Meters represent part of the cost of measuring the amount of water that is sold. This cost, termed measurement cost, represents one type of market transactions cost. Non-standard practices often evolve in cases where measurement costs are particularly high. For example, the high costs of measuring the individual contributions of members of teams may shape the organization of work and firms (Alchian and Demsetz 1972; Ouchi 1980). Similarly, large effort required to determine the value of complex goods offered for purchase may explain the existence of tie in and block booking. For example, Kenny and Klein have suggested that excessive measurement cost associated with diamond purchases may be avoided by the practice of block booking (Kenny and Klein 1983). In this paper, communal water use is explained as a practice to economize on water use measurement cost.

Communal water use may also be explained as rent seeking or perhaps as the outcome of historical accident. Non-standard practices that economize on transactions costs may evolve over time due to natural selection processes (Alchian 1959; Fama 1980; Fama and Jensen 1983). However, when resources are owned collectively, rent seeking and inefficiencies in decision-making may impede this process (Buchanan and Tullock 1965). Most water districts in the Central Valley are public and decision-making is collective.

Rent seeking and collective decision making in the formation and management of water districts has been blamed for a variety of perceived inefficiencies (Weatherford 1982). For example, the formation of public and often inefficient water districts has been explained with a

median voter model in cases where water use among district voters is skewed such that the majority may gain a differential advantage in water rates and land values at the expense of the minority by going public (Smith 1983). A similar model might be used to explain the existence of communal water systems in the urban Central Valley water districts. Districts with a sufficiently skewed water use distribution might choose communal water use because a majority within the district would benefit even though the district as a whole suffer net economic loss.

Another explanation of communal water use is that it is the adventitious outcome of numerous historical, legal, social and other forces peculiar to the Central Valley (Granovetter 1985). Following this explanation, Central Valley water use practices are historically determined and unlikely to respond predictably to a single economic change, such as high water costs.

The model used in this paper assumes that communal water use is a result of economizing rather than rent seeking or historical accident. This assumption is supported by the compatibility of the model predictions with the pattern of water use practices in the Central Valley.

A TRANSACTIONS COST MODEL OF WATER SALES PRACTICES

Our model focuses on an urban water utility facing a decision whether to meter some given segment of its services population; for example, a project has been proposed to meter some specific geographic area or customer group, and the utility has to decide whether to proceed with the project. We model this as a discrete rather than a continuous choice; thus, the question is whether or not to meter rather than how much to meter. This captures the reality that many water utilities face -- in practice, there are significant fixed costs to the utility in organizing and executing a metering program, and there are often geographical or logistic constraints that essentially fix the scale of the metering program. The Central Valley contains many residences within many urban water districts. Each district chooses the proportion of residential water service connections within the district to be fitted with meters, termed here the metering coverage (π_i). There are I districts, denoted by i , $i = 1, \dots, I$, and J_i residences within each district, denoted by j , $j = 1, \dots, J_i$.

For simplicity, the following assumptions are made about district water demand and supply. Individuals in all districts have identical demand (benefit) schedules for water ($W(q)$). The demand schedule is a decreasing monotonic function relating the volumetric price (c_i) and the quantity demanded (q) such that $\frac{\partial W}{\partial c_i} < 0$.

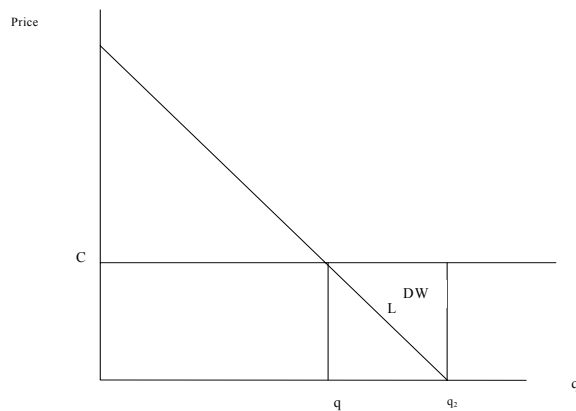


Figure 1 Water Demand and Dead Weight Loss Under Different Options for Distributing Water

A linear demand curve intersects the quantity axis at some finite value, q_2 , and the area under the demand curve is finite. The income effect, due to a price change along that curve, is assumed to be negligible. Water supply to each district exhibits constant returns and cost, C per unit for acquisition, delivery and disposal. The cost to the district of installing meters and billing each resident (k_j) varies according to residential location. The distribution of meter costs across residences is the same in all districts.

Each district i has two options for selling water to each resident j , a share option (s_{ij}) and a meter option (r_{ij}). Under the share option, a resident is charged a flat fee for water per time period and consumes q_2 units of water. Under the meter option a resident is charged a volumetric fee, based upon quantity consumed, and consumes $q_1(c_i)$ units of water, a variable quantity less than q_2 (See Figure 1).

Under both options district water revenues equal district costs. Under the share option the district delivers q_2 units of water and charges a flat fee ($q_2 c_i$) to cover the water acquisition and delivery costs. Under the meter option, the district delivers $q_1(c_i)$ units of water, an amount less than q_2 . The district charges a volumetric price of c_i and the total water bill is $c_i q_1$. The district assesses an additional fee (k_j) to cover the cost of meter installation and billing. The model assumes no additional monitoring to limit the water use of metered and non-metered residents.

The district chooses to maximize net benefits summed across all residences within the district. As the problem is defined, the district chooses between s_{ij} and r_{ij} for each resident to maximize net benefits to that resident. The district chooses the communal option, s_{ij} , when $S_{ij} > R_{ij}$, and the meter option, r_{ij} , when $S_{ij} < R_{ij}$, where capital letters denote net benefits under each option.

The net benefits to option s_{ij}

$$(1) \quad S_{ij} = \int_0^{q_2} W(q) dq - c_i q_2$$

equal the entire area under the demand curve less the cost of water. Net benefits to option r_{ij}

$$(2) \quad R_{ij} = \int_0^{q_1} W(q) dq - c_i q_1 - k_j$$

are restricted to the area under the demand curve to the left of q_2 , where marginal benefits exceed the cost of water, less the cost to supply q_2 . After differentiating (1) and (2) with respect to c_i and simplifying, it is apparent that

$$\frac{\partial S_{ij}}{\partial c_i} = -q_2$$

and

$$\frac{\partial R_{ij}}{\partial c_i} = -q_1$$

Since $-q_2 < -q_1$, and both are negative, $\frac{\partial S_{ij}}{\partial c_i} < \frac{\partial R_{ij}}{\partial c_i}$. An increase in the cost of water decreases option s_{ij} net benefits more than it decreases option r_{ij} net benefits.

Given free water ($c_i = 0$) and some positive metering cost k^* , equations (1) and (2) indicate that option s_{ij} will always be preferred to option r_{ij} , (assuming $S_{ij} > 0$). As c_i is increased indefinitely, eventually some cost c^* will be reached where

$$\int_0^{q_2} W(q) dq - c^* q_2 = \int_0^{q_1} W(q) dq - c^* q_1 - k^*$$

(3)

and $S_{ij} = R_{ij}$. If some proportion, p^* , of the residences in the district have metering costs below k^* , p^* percent of the district residences in this example will have metered service connections, and $(1 - p^*)$ percent will have share service connections.

Similarly, equations (1) and (2) indicate $\int_0^{q_2} W(q) dq - c^{**} q_2 = \int_0^{q_1} W(q) dq - c^{**} q_1 - k^{**}$ for some k^{**} , where $c^{**} > c^*$. From (3) it can be shown that $k^{**} > k^*$, which implies that over p^* of the district residences will be metered given cost c^{**} . Assuming that S_{ij} and $R_{ij} > 0$, it follows in general that $\frac{\partial p}{\partial c_i} > 0$.

EMPIRICAL APPLICATION AND DATA ANALYSIS

The model is used to explain the pattern of residential metering shown by water districts in Central Valley urban areas. Empirical analysis required the collection of secondary data as well as primary data. The California Department of Water Resources provided data on the proportion of metered connections in each city in the districts of the Central Valley. The Black & Veatch Corporation provided c_i , the unit water cost charged customers in 1999, g_i , water use per resident and n_i , city/district population. (Recall that average cost is assumed constant so that average and marginal costs are equivalent). Telephone interviews were conducted with representatives of selected water districts to obtain a range for k_i , the average cost of metering service connections, including the costs of meter installation (new and retrofit) and meter reading and billing. These data were used to supplement and update information published in California Department of Water Resources Bulletin 166-4 (August 1994) and covering 70 urban areas in the Central Valley watershed. Water use and metering data were available for 59 urban areas in 1999.

These data are analyzed using two techniques. First, the data are used to indicate the minimum water cost needed to justify residential metering and maximize net benefits, assuming average metering costs in a district and efficient water district choice of metering coverage. Second, the data are used in a logistic regression to estimate the actual change in metering associated with the change in water costs across districts in the Central Valley. A comparison between "efficient" and actual metering permits the analysis of the motivation explaining district water metering choice.

Benefit Cost Criteria For Choosing Between Water Sales Options

The switch from option s to option r represents a trade off between the benefits and the costs of metering. When a meter is installed, water use drops but metering costs become positive. Hence, the net benefit of the switch varies according to the expected drop in water use, the value of the drop in water use and the cost of metering.

The 59 urban districts which provided water use and metering data may be split into three groups: (1) districts where all residents have water meters; (2) districts where no residents have water meter meters; and (3) districts where some residents have meters and some residents do not have meters. These three groups contain 27, 10 and 22 districts, respectively, in our sample (See Table 1).

TABLE 1: Metering Practices and Water Cost in Selected Cities in the Central Valley (1999)

County	Serving	Percent Metered Single Family (%)	Annual Charge per cubic meter (\$2000)
Stanislaus	Denair	0.000	390
Fresno	Fresno	0.000	300
Fresno	Kingsburg	0.000	500
San Joaquin	Lodi	0.000	310
Madera	Madera	0.000	240
Stanislaus	Modesto	0.000	540
Sacramento	Sacramento	0.000	350
Kern	Shafter	0.000	560
Sacramento	Sacramento Unincorporated	0.000	160
Yolo	Woodland	0.000	180
Fresno	Reedley	0.000	160
Sacramento	Carmichael	0.002	590
Merced	Atwater	0.002	390
Stanislaus	Turlock	0.003	310
Madera	Chowchilla Incorporated	0.015	400
Yuba	Roseville	0.077	220
Yuba	Marysville & Vicinity	0.118	490
Sacramento	Sacramento Et Al	0.134	350
Sacramento	Elk Grove	0.183	150
Merced	Merced	0.216	440
Kern	Bakersfield And Vicinity	0.247	350
Tulare	Tulare	0.260	330
Sacramento	Fair Oaks/Orangevale	0.275	540
Fresno	Firebaugh/Las Deltas	0.277	510
Tulare	Visalia & Vicinity	0.311	340
Fresno	Selma	0.359	550
Butte/Glenn	Chico & Vicinity, Hamilton & Vicinity	0.378	360
Kings	Corcoran	0.380	470
Yuba	Yuba City	0.860	250
Fresno	Clovis/Tarpey Village	0.939	380

Tulare	Porterville	0.958	390
Yolo	Davis/El Macero	0.967	320
Kern	Arvin	1.000	400
Placer	Auburnbowma	1.000	580
Kern	Bakersfield	1.000	360
Placer	Brockway/Kings, Beach/Tahoe Vista	1.000	970
Shasta	Burney	1.000	310
Fresno	Coalinga	1.000	710
Colusa	Colusa	1.000	280
Kern	Delano	1.000	370
Merced	Delhi	1.000	300
Tulare	Dinuba	1.000	360
El Dorado	El Dorado Hills Et Al	1.000	530
Tulare	Exeter	1.000	200
Merced	Hilmar	1.000	390
Kings	Lemoore	1.000	370
Tulare	Lindsay	1.000	410
Merced	Los Banos	1.000	220
San Joaquin	Manteca	1.000	320
Sacramento	Rancho Murieta	1.000	670
Tehama	Red Bluff	1.000	380
Shasta	Redding	1.000	390
San Joaquin	Stockton	1.000	540
Kern	Taft Et Al	1.000	540
Kern	Tehachapi	1.000	380
San Joaquin	Tracy	1.000	930
Placer	Auburn Unincorporated	1.000	580
Nevada	Grass Valley Area Unincorporated	1.000	670

The average cost of water in 100% metered districts was \$480 per km³ (km³ in \$2000) while the average cost of water in 100% non-metered districts was \$350/ km³. The average annual water use per residence in metered and non-metered was 340 m³ and 420 m³, respectively, a 25% difference. As a first approximation, these data suggest that a switch from a share to a meter option, to a resident in a district where the cost of water was \$480/ km³, would decrease water use 80 km³. This amount may be termed excessive water use because it has a marginal value less than its marginal cost. A non-metered residence will always have some excessive water use because each resident acts as though his marginal cost of water were zero.

The value of a drop in water use to a resident equals the avoided cost of the resident's excessive water use. The net value of the drop in water use is termed dead weight loss (DWL). If we assume a linear demand for water, half the cost of excessive water use by a non-metered residence is dead weight loss (See Hanke 1982). For example, given a linear demand for water between \$480/ km³ and \$0/ km³, the DWL associated with the 80 m³ excessive water use is \$20 (See Figure 1). Using these same linear assumptions, the DWL associated with water costing \$320/ km³ is about \$13.64, the DWL associated with \$160/ km³ water is about \$6.82, and the DWL associated with \$80/ km³ water is about \$3.41. Six urban water districts provided cost data based upon recent or on-going metering programs (Table 2). These data indicate that metering costs within a district are quite variable and have a bimodal distribution, reflecting the difference between the costs of retrofitting meters into older residences and installing meters in new residences. Based upon these data, the annual cost of meter installation, reading and billing is estimated to average \$37.18 for a retrofit and \$14.54 for a new residence meter (Table 2).

TABLE 2: Cost of Meter Installation, Meter Reading and Billing (2000\$)

1. Survey Results

Municipal Utility	Meter Installation	Reading and Billing
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	Retrofit	New	(Annual Cost)
Chico	\$225.32	\$105.15	
Fresno	\$ 255.36	\$ 82.62	
Redding		\$ 97.64	
Sacramento Citizens	\$193.77		
Sacramento County	\$781.10		\$ 7.90
Stockton	\$ 225.32	\$100.00	\$ 3.00
2. Average Cost	\$336.17	\$96.35	\$ 5.45
3. Annual Cost	\$31.73	\$9.09	
to Install (Amortized over 20 year life @ 7%			
4. Total Cost	\$ 37.18	\$ 14.54	
(Including Reading and Billing Cost			

A switch from option s to option r is warranted only when avoided DWL is greater than acquired metering costs. The estimates above suggest this to be the case on average for retrofit metering, only when the cost of water is above \$0.9/ m³. Avoided DWL exceeds the cost of new residence metering when the cost of water is over \$0.3/ m³.

Logistic Regression Analysis of Water District Choices

Benefit-cost criteria might assist district residents to choose between options S and R for distributing water. An econometric analysis was done to determine whether similar benefit-criteria affect this choice in practice. Specifically, a logistic regression was run to estimate the change in metering proportion associated with a unit change in water costs across districts in the Central Valley.

The logistic regression estimates the metering-water cost relationship assuming a function of the form $y = b_1 + b_2 c + b_3 pop + e$ where b1, b2, and b3 are coefficients to be estimated, ci is district average water cost, pop is city population, e is the error term having a zero mean and Weibull distribution, and y represents the logistic transformation of pi equal to:

$$y = \ln \frac{p_i}{1 - p_i} \text{ if } 0 < p_i < 1$$

$$y = \ln \frac{p_i + \frac{1}{n}}{1 - p_i + \frac{1}{n}}, \text{ if } p_i = 0$$

$$(4) \quad y = \ln \frac{p_i - \frac{1}{n}}{1 - p_i}, \text{ if } p_i = 1$$

in order to perturb the data from the boundary conditions (Cox 1970). Recall that pi is the proportion of residences in a district with water service connections that are metered and n is the number of observations in the regression sample. Equation (4) may then be estimated using ordinary least squares (Cox 1970).

These factors entered into the regression of district metering proportions:

Variable	Coefficients	Standard Error	t Stat
Intercept	-1.32020732	2.676082516	-0.49334
Annual Charge in \$2000	0.00980136	0.004606344	2.127796
Population	-2.9654E-05	1.11604E-05	-2.65709
Adjusted R ² = .16			
59 observations			

The estimated coefficient and associated t-statistic in the regression equation indicates that the water cost variable is positive and significant, as predicted by the model. Population is inversely related to metering proportion and is statistically significant. We hypothesize that larger

communities in the Central Valley were established long before metering became more commonplace and are thus less likely to be metered. This equation may be used to predict the long run increase in metering caused by changes in the water cost. For example, the equation indicates a 72% metering proportion given \$0.3/ m³ water and indicates a 100% metering proportion, given \$0.9/ m³ water. In this range, a \$690 increase in the cost of water is associated with a 28% increase in metering.

It is noteworthy that district choice of metering options, as summarized in the regression equation, is compatible with the benefit cost criterion for maximizing district net benefits, presented in the example above. Recall that these criteria indicate that retrofit metering is economic, given above \$0.9/ m³ water, and new residence metering is uneconomic given below \$0.3/ m³ water, assuming average costs for retrofit and new residence meters.

In other words, district metering in the Central Valley is probable (100%), when the benefit cost criterion indicates retrofit metering of existing residences is economic, and district metering is less probable (72%), when benefit cost criterion indicates metering new residences is not economic. This comparison between metering practice and metering benefits and costs, suggests that water districts choose metering proportions in large part on efficiency grounds. The data on water costs and metering proportions in different districts illustrate this point most directly. It is generally not correct to accuse water districts of inefficiency merely because district residences are not metered.

CONCLUSION

Metering proportions of Central Valley water districts are explained using a model that postulates maximization of district net benefits. Predictions of metering proportions, based upon this model, are compatible with the empirical data. These findings suggest that share water systems in the Central Valley are an efficient response to low water costs.

This analysis only considers the direct cost of water and meters to districts. Broader considerations, such as the volume and quality of return flows and possible under-pricing of water are not dealt with and could modify this conclusion. Nevertheless, these findings also suggest that legislative effort to end share water systems may be misguided. More fundamental inefficiencies in California water use, such as uncertain water rights, hinder water sales between districts and may keep Central Valley water prices artificially low. Legislative effort might be more effective if it were directed to solve these fundamental problems rather than to impose water meters upon Central Valley water districts.

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